The Observed Motion and Duration of the Radiant Point of the Perseids. By W. F. Denning.

In recent years a considerable number of observations have been made of the great display of *Perseids* in July and August, and the time seems to have arrived when the results may be usefully summarised. The writer called attention to the motion of the radiant in 1877 August, and reobserved this peculiarity in 1878, 1880, 1885, 1886, 1887, and in several subsequent years. Mr. D. Booth at Leeds obtained some special observations in 1888 and 1891 in examination of this feature, and his figures closely accorded with those previously derived at Bristol (*Observatory*, vol. xi., p. 380).

In tracing the displacement of a radiant it is necessary to keep the observations for each night separate, so that the individual centres for a series of dates may be determined and compared. Before 1893 it appears to have been customary to combine the materials accumulated on several successive or bordering nights, and thus the radiant points, based on such collections, formed diffused positions giving little or no intimation of motion. The necessity of confining the reductions to shorter periods was, however, impressed upon observers, so that in and since the very favourable year 1893 the observations employed in the deduction of the *Perseid* radiant have usually been limited to a single night, and the places determined in this way have proved of much value as evidence in respect of the E.N.E. motion of the shower centre. In the summary which follows I have arranged the radiants observed at Bristol in and since 1874 according to the day of the month on which they were made, and in a separate table have given similar observations by others in and since 1893,* for comparison. It was thought essential to keep the two sets of positions distinct, inasmuch as the Bristol results, if incorporated with the rest, might have unduly influenced the mean values and the deductions based on them. In fact, it seemed safer to arrive at conclusions justified by independent testimony, and to show the degree of mutual corroboration existing between the results derived at Bristol and at other stations. On inspection of the tables this will be seen to be very satisfactory when the nature of the observations is considered. During the last ten years quite a large number of observers have distinguished and followed, as far as conditions permitted, the easterly drift of the radiant, and the rate and direction of the movement have been pretty accurately assigned. As an observational fact this motion cannot be questioned. The writer has long regarded it as one of the most palpable, as well as

* An exception has, however, been made in regard to Mr. Booth's results obtained in 1888 and 1891, as he fixed the place of the radiant from observations on single nights.

one of the most certain, features he has ever noticed in this field of observation. And this trait in the visible character of the *Perseids* is one which appears to be in significant harmony with theory.

Judging from the remarkable increase in meteoric observers in recent years there seems every reason to suppose that the *Perseid* shower (offering as it does a rich display, appearing regularly at the most congenial season of the year) will be more critically studied, and that its radiant point will often be traced as it passes from the southern stars of *Cassiopeia* along the northern borders of *Perseus* into *Camelopardalis*. No doubt this transitory character of the centre is not a feature which is apparent only in the behaviour of the *Perseids*. It is similarly exhibited by the April *Lyrids* and probably by certain other systems, but they are displayed so briefly and often so feebly that it is difficult to glean a sufficient number of well-observed meteors to fix their radiants accurately on nights near the limits of their visibility. On the other hand, a movable radiant is not a common feature, for certain well-defined showers, among which may be instanced the October *Orionids*, show stationary radiants. These peculiarities require further investigation in regard to many of the principal streams. It seems desirable that the *Quadrantids* or *Boötids* of January, the *Lyrids* of April, the *Aquarids* of May and July, the *Orionids* of October, the *Leonids* and *Andromedids* of November, and the *Geminids* of December should all be perseveringly watched in future years with particular regard to their visible durations and to the mobile or fixed radiants which they individually display.

The abbreviations in the list of *Perseid* radiants determined by various observers are :—

E. M. A.	...	E. M. Antoniadi, Juvisy.
W. E. B.	...	W. E. Besley, London, S.W.
E. R. B.	...	E. R. Blakeley, Dewsbury.
D. B.	...	D. Booth, Leeds.
J. H. B.	...	J. H. Bridger, Farnborough.
H. C.	...	H. Corder, Bridgwater.
W. D.	...	W. Doberck, Hong Kong.
J. A. H.	...	J. A. Hardcastle, Littlemore, Oxon.
A. S. H.	...	A. S. Herschel, Slough.
W. H. M.	...	W. H. Milligan, Belfast.
C. D. P.	...	C. D. Perrine, Lick Observatory.
T. E. R. P.	...	T. E. R. Phillips, Yeovil.
H. J. T.	...	H. J. Townshend, Leeds.

The observations at Bristol were made at Bishopston, a suburb about two miles north of the central part of the city. During the years from 1869 to 1901 inclusive I observed 8,002 shooting stars on the forty-three nights between July 11 and August 22 inclusive, and these included 2,856 *Perseids*.

With reference to the theoretical conclusions on the displacement of apparent radiant points there is a valuable paper in *Monthly Notices*, vol. lii., pp. 341–54, by the late Joseph Kleiber. Mathematical deductions are here compared with some observational results, and in the case of the *Perseids* they present an excellent accordance. Mr. Kleiber gives the computed place of the radiant on July 8 as 9°+46°, August 8 41°·5+57°·3, August 9 42°·9+57°·6, August 10 44°·2+57°·9, and August 16 54°+59°. Le Verrier first pointed out that theoretically such a displacement must occur, and in 1859 some visible indications of it were recognised by Professor A. C. Twining in America, but the observations were too meagre and inaccurate to prove anything conclusively.

In the lists of radiants I have included those of several very early or late *Perseids* whose real paths were determined from two or more observations, as the places afford a useful corroboration of the radiant positions of the shower at times when it has been but scantily recorded. The real paths and radiants of several hundreds of *Perseids* have been found for dates between August 1 and 14, but it has not been thought desirable to include these, as they were nearly all recorded on August 9, 10, or 11, when the situation of the radiant has been sufficiently well indicated from other observations. The letters "F" and "SS" refer to radiants deduced from duplicate observations of Fireballs and Shooting Stars respectively.

Radiant Points of the Perseids observed by W. F. D.

		α °	δ °	↙'s
1877–8	July 8–13	11	+48	10
1876–7	July 18	17	+50	4
1900	19	17	+50	SS
1887		19	+51	4
1901	21	23	+52	5
1887	22	25	+52	5
1887	23	25	+52	4
1900		24	+52	SS
1900–1 &c.	24	23	+52	5
1900–1	25	22	+52	5
1878	26	30	+53	5
1887	27	29	+54	5
1883	28	27	+55	10
1887		30	+55	10
1878		32	+53	10
1879		32	+53	9
1887	29	31	+54½	10
1878	July 30	32	+53	12
1898		23	+53	SS
1900		30	+52	F
1900		31	+54	10
1899	July 29–Aug. 2	34	+54	8
1878	July 31	32	+53	20
1877		35	+54	11
1878	Aug. 1	32	+54	10
1887		36	+56	4
1897	1–2	36	+56	13
1886	2	33	+55	12
1888		35	+54	14
1881		39	+55	14
1877	3	39	+55	7
1886	4	37	+57	12
1877		41	+56	6

			α	δ	↙'s
1893	Aug.	5	39	+55	4
1888			42	+57	11
1896		6	42	+56	7
1887			42	+55	5
1899			40	+55	6
1877		7	40	+56	7
1899			41	+58	10
1880			41	+55	14
1887			43	+56	5
1895			41	+57	5
1880		8	41	+55	23
1893			41	+56	12
1888			42	+57	20
1887			43	+56	5
1893		9	43	+57	20
1880			44	+55	71
1899			44	+57	26
1879			46	+58	38
1874		10	44	+58½	252
1876			43	+59	43
1877			43	+58	285
1878			42½	+54	106
			44	+59	
1880			45	+57	41
1882			43	+57	8
1884			44	+59	16
1886			44	+57	122
1887			42½	+57½	22
1893			45	+57	14
1895			45	+55	17
1896			45	+57	69
1899			44	+57	72
1901			44	+58	55
1880		11	48	+57	43

			α	δ	↙'s
1882	Aug.	11	46	+57	45
1886			47	+57	15
1887			45	+57½	16
1895			44	+58	7
1899			46	+57	69
1901			45	+58	49
1898			46	+58	106
1880		12	48	+57	19
1877			50	+55	14
1899			48	+5	43
1893			48	+58	7
1896			46	+57	7
1880		13	49½	+57½	7
1888			52	+57	13
1885			51	+58	6
1899			49	+58	10
1893			48	+58	8
1899		14	50	+56	12
1893			49	+57	7
1887			53	+57	8
1901		15	51	+58	6
1901			56	+58	SS
1901			52	+53	F
1884–5		15–16	53	+59	5
1893		16	52	+57	4
1899			53	+57	7
1900			54	+58	5
1901			53	+58	5
1885–91		17	54	+60	5
1893–1901		18	55	+59	11
1884–1901		19	57	+59	5
1901		20	57	+58½	6
1901		21	61	+59	7
1900–1		22–3	59	+59	5

Radiant Points of Perseids determined by various Observers.

			α	δ	↙'s	
1900	July	19	15	+49	SS	A.S.H.
1897		22–7	23	+49	17	A.S.H.
1900		23	23	+51	5	W.E.B.
1900	July	23	20	+51	SS	A.S.H.
1900			27	+54	SS	A.S.H.
1897		23–4	24	+50	5	A.S.H.

		α	δ	↙'s	
1900	July 24	25°	+52½°	7	W.E.B.
1897	25	22	+52	4	H.C.
1888	26	20	+55	5	D.B.
1891	27	28	+58½	7	D.B.
1898	29	31	+54	5	E.R.B.
1897	30	37	+53	4	H.C.
1900		30	+54	4	E.M.A.
1900	July 30 –Aug. 1	33	+54½	4	J.H.B.
1897	July 30 –Aug. 2	27	+53	24	A.S.H.
1897	Aug. 1	33	+56	4	E.R.B.
1899		30	+54½	5	J.H.B.
1895	2	35	+55	16	E.R.B.
1897	3	32½	+57	6	W.E.B.
1901		35	+56	...	E.M.A.
1895	3–4	43	+57	6	W.H.M.
1895	4	38	+54	5	E.R.B.
1891		39	+57	11	D.B.
1893	5	39	+54	4	E.R.B.
1896		37	+57	10	W.H.M.
1897	2–8	36	+55	17	A.S.H.
1894	6	38	+56	15	E.R.B.
1894		45	+57	8	W.H.M.
1894		45	+57	15	H.C.
1895	7	39	+53	11	E.R.B.
1895		40	+56	7	H.C.
1900		39	+54	5	J.H.B.
1888	8	42	+57½	21	D.B.
1893		42	+55	21	E.R.B.
1894		47	+57	4	H.C.
1893	9	44	+55	9	E.R.B.
1894		41¼	+54½	...	C.D.P.
1894		42	+56	17	E.R.B.
1893		43	+57	15	D.B.
1895		43	+57	23	H.C.
1896		40	+58	22	W.H.M.
1897		42	+56	21	A.S.H.
1897		51	+57	19	A.S.H.
1897		45	+57	17	H.C.
1897	Aug. 9	43½°	+57½°	71	W.E.B.
1898		42	+55½	10	J.H.B.
1899		41	+55½	8	J.H.B.
1899		44½	+57	7	A.K.
1901		41	+57	...	E.M.A.
1901		40	+55	4	J.H.B.
1893	10	44	+56	50	E.R.B.
1893		45	+57	17	W.H.M.
1893		44	+57½	100	H.C.
1894		46	+55	...	C.D.P.
1894		42	+56	49	E.R.B.
1894		45	+51	15	H.J.T.
1896		46	+57	11	J.A.H.
1896		43	+58	20	E.R.B.
1896		47½	+58	...	D.B.
1896		47	+58	30	H.C.
1898		43	+55½	16	J.H.B.
1898		43	+59	11	H.C.
1898		45	+55	...	T.E.R.P.
1898		43	+53	...	H.J.T.
1899		43	+56	12	J.H.B.
1899		45	+57	29	A.K.
1899		45	+58	54	W.E.B.
1899		45	+56	84	E.M.A.
1901		43	+56½	7	J.H.B.
1893	11	44½	+57½	23	W.D.
1894		44	+65	...	C.D.P.
1895		45	+56	13	E.R.B.
1895		43	+58	...	A.S.H.
1895		43½	+58	72	H.C.
1896		45	+55	43	E.R.B.
1898		45	+58	40	W.E.B.
1898		45	+56	13	J.H.B.
1898		49	+58	13	H.C.
1898		46	+58	...	T.E.R.P.
1898		46	+56	29	H.J.T.
1898		45	+58	30	E.R.B.
1899		45	+57	18	J.H.B.
1899		45	+57	8	W.E.B.

			α	δ	↙'s	
1899	Aug	11	46°	+57°	17	A.K.
1899			46½	+56	116	E.M.A.
1900			43	+56½	6	J.H.B.
1901			46½	+57	14	A.K.
1901			44½	+56½	9	J.H.B.
1893		12	44	+56	26	E.R.B.
1896			48	+57	6	E.R.B.
1896			48	+60	30	H.C.
1899			46	+56⅓	10	J.H.B.
1899			46	+57	6	E.M.A.
1899			46½	+58	7	A.K.
1899			48	+58	15	W.E.B.
1900			48	+58	12	A.K.
1901			47	+58	13	A.K.
1901			44	+57	...	E.M.A.
1888		13	51½	+56	17	D.B.
1895			51½	+56½	14	H.C.
1896			50	+59	10	E.R.B.
1899			48	+55	15	E.M.A.
1899			49	+57	5	A.K.
1899			49	+58	10	E.M.A.
1899		13–14	49	+58	8	A.K.
1888		14	55	+59½	5	D.B.
1891	Aug.	14	56°	+58½°	8	D.B.
1893			49	+55	10	E.R.B.
1893			54	+59	...	H.C.
1895			51	+58	6	E.R.B.
1896			51	+59	24	E.R.B.
1899			50	+58	5	W.E.B.
1900			50	+56	5	E.M.A.
1891		15	58½	+59½	6	D.B.
1893			51½	+59	...	E.R.B.
1893			55	+57	5	H.C.
1896			50	+58	8	W.H.M.
1901			51	+58	4	A.K.
1901			48	+58	5	J.H.B.
1901			53	+58	...	E.M.A.
1901			54	+53	F	A.S.H.
1901			58	+58	SS	A.S.H.
1893		17	58	+62	7	E.R.B.
1893		18	54	+62	...	E.R.B.
1893			51	+56	11	H.C.
1901		19	53	+58	...	E.M.A.
1893		21	55	+57	3	W.H.M.
1893			55	+65	6	W.H.M.

Mean Radiant Points of Perseids.

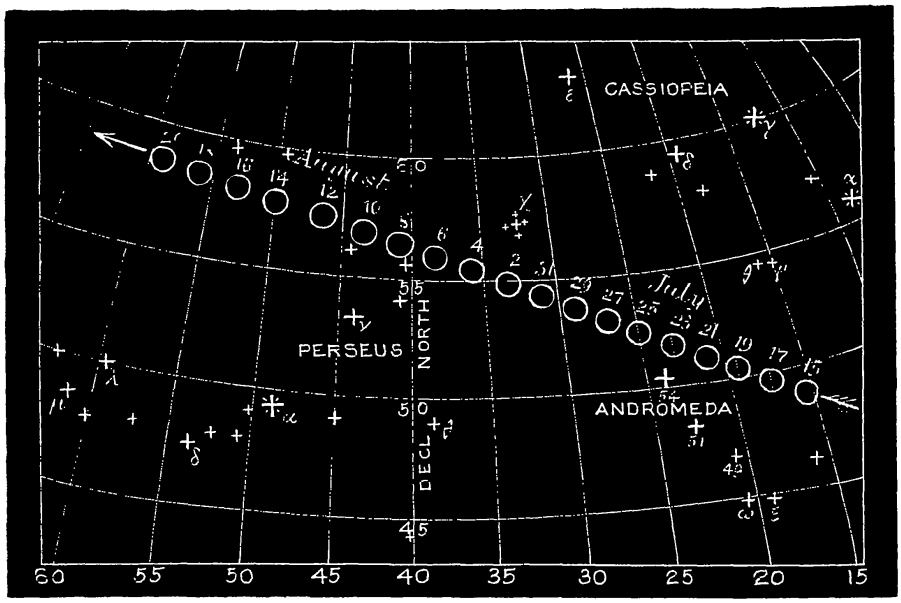
	W.F.D. α	W.F.D. δ	Radiants.	Other Observers. α	Other Observers. δ	Radiants.	Mean of all. α	Mean of all. δ	Radiants.
July 8–13	11°·0	+48°·0	1	...	...	...	11°·0	+48°·0	1
18	17·0	+50·0	1	...	...	...	17·0	+50·0	1
19	18·0	+50·5	2	15·0	+49·0	1	17·0	+50·0	3
20	...	...	...	...	...	...	...	...	...
21	23·0	+52·0	1	...	...	...	23·0	+52·0	1
22	25·0	+52·0	1	...	...	...	25·0	+52·0	1
23	24·5	+52·0	2	23·3	+52·0	3	23·8	+52·0	5
24	23·0	+52·0	1	25·0	+52·5	1	24·0	+52·2	2
25	22·0	+52·0	1	22·0	+52·0	1	22·0	+52·0	2
26	30·0	+53·0	1	20·0	+55·0	1	25·0	+54·0	2
27	29·0	+54·0	1	28·0	+58·5	1	28·5	+56·3	2
28	30·2	+54·0	4	...	...	...	30·2	+54·0	4
29	31·0	+54·5	1	31·0	+54·0	1	31·0	+54·2	2

		W.F.D. α	W.F.D. δ	Radiants.	Other Observers. α	Other Observers. δ	Radiants.	Mean of all. α	Mean of all. δ	Radiants.
		°	°		°	°		°	°	
July	30	29·0	+53·0	4	33·5	+53·5	2	30·5	+53·2	6
	31	33·7	+53·7	3	33·0	+54·5	1	33·5	+53·9	4
Aug.	1	34·0	+55·0	2	31·5	+55·3	2	32·8	+55·1	4
	2	35·7	+54·7	3	35·0	+55·0	1	35·5	+54·7	4
	3	39·0	+55·0	1	33·7	+56·5	2	35·5	+56·0	3
	4	39·0	+56·5	2	38·5	+55·5	2	38·8	+56·0	4
	5	40·5	+56·0	2	37·3	+55·3	3	38·6	+55·6	5
	6	41·3	+55·3	3	42·7	+56·7	3	42·0	+56·0	6
	7	41·2	+56·4	5	39·3	+54·3	3	40·5	+55·6	8
	8	41·7	+56·0	4	43·7	+56·5	3	42·6	+56·2	7
	9	44·2	+56·7	4	42·9	+56·3	15	43·2	+56·4	19
	10	43·9	+57·3	15	44·4	+56·3	19	44·2	+56·8	34
	11	45·9	+57·4	8	45·1	+57·4	19	45·3	+57·4	27
	12	48·0	+56·8	5	46·5	+57·5	10	47·0	+57·3	15
	13	49·9	+57·7	5	49·8	+56·9	6	49·9	+57·3	11
	14	50·7	+56·7	3	52·0	+57·9	8	51·6	+57·5	11
	15	53·0	+56·3	3	53·2	+57·6	9	53·2	+57·3	12
	16	53·0	+57·5	4	...	...	...	53·0	+57·5	4
	17	54·0	+60·0	1	58·0	+62·0	1	56·0	+61·0	2
	18	55·0	+59·0	1	52·5	+59·0	2	53·3	+59·0	3
	19	57·0	+59·0	1	53·0	+58·0	1	55·0	+58·5	2
	20	57·0	+58·5	1	...	...	...	57·0	+58·5	1
	21	61·0	+59·0	1	55·0	+61·0	2	57·0	+60·3	3
	22–3	59·0	+59·0	1	...	...	...	59·0	+59·0	1
				99			123			222

It will be seen from the mean positions of the radiant that the R.A. does not exhibit a regular diurnal increase, but that some marked irregularities are apparent. These are obviously due to errors of observation, which in certain cases have been large, and which, even in the most accurate results, have not been wholly eliminated. If the mean values for the radiant from all the observations are grouped into five-day periods the increase in the R.A. and N. Dec. becomes well defined, as follows :—

Period.	Mean Place of Radiant. α	Mean Place of Radiant. δ	Number of Radiants.
	°	°	
July 18–22	20·5	+51·0	6
23–27	24·7	+53·3	13
28–Aug. 1	31·6	+54·1	20
Aug. 2–6	38·1	+55·7	22

Period.	Mean Place of Radiant. α	δ	Number of Radiants.
	°	°	
Aug. –11	43·2	+ 56·5	95
12–16	50·9	+ 57·4	53
–22	56·2	+ 59·4	12



Positions of the Perseid Radiant Point, July 15 to August 20.

From the whole of the observations I have drawn up the following ephemeris, but the figures are not intended to simply represent the curve deduced from them, certain corrections having been applied. The year 1900 not being Leap Year, and nearly all the materials having accumulated before that year, the result is that the position of the radiant will be about 1° less in R.A. in the immediate future than on the same date before 1900. In fact, the maximum displays of the shower will occur a day later, and be witnessed either on August 11 or 12. I have allowed for these effects, and also for the circumstance that my own observations and a certain proportion of the others required a small correction for precession. A few of the observed radiants included in the tables are undoubtedly erroneous, from their discordance with others of contemporary date, and all such positions should be excluded in attempts to derive reliable places for the shower.

It is to be hoped that observers will carefully test the degree of accuracy of the ephemeris, either by photographs of meteor trails or by very exact eye-observations, in future years. I think it quite possible that the radiant should be placed a little farther north, particularly at about the period of the maximum, for the presence of the stars γ and η *Persei* just south of the radiant must probably have exercised a slight influence in leading

observers to place the centre too far south. It is often found that when a bright or fairly conspicuous star is situated near a radiant the latter is apt to be assigned nearer to the star than the truth requires. The ephemeris gives the R.A. of the radiant as less than that indicated in the similar table published in *Memoirs*, vol. liii., p. 210; but this is to be chiefly ascribed to the alteration rendered necessary by the absence of leap year in 1900, and moreover the present ephemeris has been independently formed from more extensive materials than could possibly be employed in the previous case :

Ephemeris of the Perseid Radiant Point.

	α	δ		α	δ
	°	°		°	°
July 15	15·3	+48·9	Aug. 3	35·1	+55·3
16	16·2	+49·3	4	36·4	+55·5
17	17·1	+49·7	5	37·6	+55·7
18	18·0	+50·1	6	38·9	+56·0
19	18·9	+50·5	7	40·2	+56·2
20	19·8	+50·8	8	41·5	+56·5
21	20·8	+51·1	9	42·9	+56·7
22	21·8	+51·5	10	44·3	+56·9
23	22·8	+51·8	11	45·7	+57·1
24	23·8	+52·2	12	47·1	+57·3
25	24·9	+52·5	13	48·5	+57·5
26	26·0	+52·8	14	50·0	+57·7
27	27·1	+53·2	15	51·4	+57·8
28	28·2	+53·5	16	52·9	+58·0
29	29·3	+53·8	17	54·4	+58·2
30	30·5	+54·1	18	55·9	+58·4
31	31·6	+54·4	19	57·4	+58·5
Aug. 1	32·7	+54·7	20	58·9	+58·7
2	33·9	+55·0			

Probably the display commences in a very feeble form before July 15, and is continued to a later date than August 20. In the third week of July the shower is, however, very liable to be confused with a radiant of swift, streak-leaving meteors directed from near γ *Andromedæ* (24°+43°); and in the third week of August it becomes apparently blended with a shower of *Camelopardids* (60°+59°).

Bishopston, Bristol: 1901 *November* 10.

Note on a Large Fireball. By W. F. Denning.

At $5^h\ 36^m$, soon after dark on the very clear frosty evening of December 4 last, a fireball of exceptional brilliancy was observed from various parts of the country. It gave a flash of dazzling intensity, illuminating the English Channel and South of England with a light stronger than that of the full Moon. The fireball had a bluish-green head, and along the more luminous section of its flight it projected a train or streak of orange-red material, which remained visible to the eye from a few seconds to five minutes according to the various estimations made by different persons.

The position of the train amongst the stars was carefully noted by several observers. Admiral Maclear at Chiddingfold, Surrey, found it to extend from $290\frac{1}{2}° + 11\frac{1}{2}°$ to $295\frac{1}{2}° + 5\frac{1}{2}°$, and Mr. G. F. Oldham, of Tunbridge Wells, Kent, says it was 7° or 8° long and placed midway between o *Herculis* and χ *Aquilæ*, and in a straight line with these stars and the planet *Venus*. The Rev. W. F. A. Ellison, of Dublin, saw the fireball as it flashed out in *Cetus*, low in the S.E., and the place of the lingering train was from $7° - 10°$ to $16° - 16°$. From these and some additional descriptions which I have compared the real path appears to have been as follows :

Height at beginning	...	91 miles over English Channel, 11 miles S. of Bridport, Dorset.
Height at ending ...	...	50 miles over English Channel, 15 miles S. of Needles, Isle of Wight.
Length of path ...	...	64 miles.
Approximate velocity	...	21 miles per second.
Earth point ...	...	37 miles S. of Brighton.
Height of streak ...	...	72 to 55 miles.
Length of streak ...	...	26 miles.
Radiant point ...	...	$263° + 36°$.

These results approximately represent a portion of the course. The whole of the luminous flight of this brilliant *Herculid* fireball may quite possibly have extended further, both at the beginning and end, but precise limits cannot be assigned, many of the observations being indefinite and some of them contradictory on this point.

Bishopston, Bristol: 1901 *December* 10.